Opting for Science and Technology!

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Efforts aimed at solving the enormous shortage of higher education graduates in science and technology in the Netherlands should start by evaluating what is available in this area. Research shows that the country's vast resources include considerable reserves of science and technology talent. These reserves comprise students who, although having met the entry requirements, ultimately did not opt for a technical or science study programme. Several measures could mobilise these reserves; some are presented in this article along with the influence they are estimated to have. Although

Introduction

From an international perspective, the Dutch economy is struggling with sluggish growth in productivity. In its policy recommendation *Towards a plan for productivity in the Dutch production industry* the Foundation for Industrial Policy and Communication (SIC, 2003) points out that the low level of expenditure on research and development (R&D) is one of the causes. Research further indicates that the effectiveness of technology grants provided to stimulate R&D would be greater with a larger supply of knowledge workers with a science/technology (sci/tech in short) background. Not only are more technicians needed, the technological changes notably require technicians also to be more highly educated. This is particularly so if the Netherlands wants to reach its goal of becoming one of the leaders of the European knowledge-based economy.

The Netherlands is not alone, though, in wanting to increase the science and technology content of the working population. On 5 May 2003, the European ministers of education issued a joint declaration in Brussels to the effect that more science and technology students will be needed to maintain the required level of the knowledge-based economy (Education Council, 2003). The Council wants to increase the number of relevant students by 15 % between now and 2010, while giving appropriate attention to improving the man/woman ratio. The communiqué does not indicate, however, exactly how this increase is to be realised.

The problem of shortages in science and technology has not arisen overnight. In November 1992, The Economist reported that: '... universities continue to churn out humanities-trained generalists at a time of soaring demand for scientists and engineers'. In the Netherlands over the past 10 years, the alarm has been sounding over the problem of the (insufficient) influx into science/technology. In 2003, industry was still complaining about (threatening) shortages of technically trained personnel. At the same time, universities feared underutilisation and the eventual abolition of courses in science and technology. With the prospect of the dramatic outflow of university staff reaching pensionable age in the coming years, this development is cause for alarm.

Certain actions were taken in addition to sounding the alarm. For example, more than 10 years ago, the government conducted the not very successful campaign Kies Exact (Choose Science). Recently the system of secondary professional education was restructured with a view to stimulating the number of students choosing science/technology, though its success is controversial. The government and employers have jointly carried out a large number of projects aimed at promoting science/technology in education, and with the implied need to engage seriously in full implementation of the best practices found. Following the Confederation of Netherlands Industry and Employers VNO-NCW, the government has started a Delta Plan for science and technology, and funds are available for this purpose.

In this article, we will be seeking an answer to the question: 'How much sci/tech talent is actually available in the Netherlands?' That not all talent will opt for a technical education should be considered obvious. After showing the extent of talent available, the question is how this talent can be induced to opt for technology. The work is based on data from different databases (see Annex 1).

Definitions

In the Netherlands the system of higher education is split between professional higher education (PHE) and academic higher education (AHE). The latter is generally more theoretical and considered superior. Pupils from pre-university secondary education (VWO) can, after graduation, choose between PHE and AHE. In contrast, pupils with a diploma from intermediate vocational education (MBO) or senior general education (HAVO) can only enrol in PHE. In Annex II the Dutch education system is described in more detail.

Talent

Before being able to deal with the question of whether there is sci/tech talent in the Netherlands, we first need to define the concept of sci/tech talent. It takes little effort to agree the designation 'talent' in this context. When, in this paper, reference is made to sci/tech talent, this means that the pupil who goes to secondary school studies (or, for students, has studied) the right range of subjects to be admitted to studies in science or technology. This may conceivably be linked to a quality requirement: for example, the condition that the final marks obtained for these subjects meet at least a certain minimum.

Prior to introducing optional subject clusters in secondary education, the requirement for admission to studies in science or technology used to be at least mathematics and physics among the subjects chosen. Research into files of first-year students of the 1991 cohort showed that, in addition to the number of sci/tech subjects, the average final examination mark increases the chance of obtaining the first-year certificate of a study in science or technology (de Jong et al., 1998).

The most recent students entering higher education had not chosen any specific subjects in secondary education, as they would have under the old system, but rather a particular subject cluster. The first of two decision points which could lead to education in science/technology, coincides with the moment pupils must choose a subject cluster in secondary school. The second is choosing the particular study option. So, in addition to delineating talent among students in higher education, we can also distinguish sci/tech potential among pupils in secondary education. To this effect, we select pupils with the optional nature and technology or nature and health subject cluster.

Reserves

To gain a proper picture of the science and/or technology potential available in the Netherlands, we also look at the group of pupils/students who, although meeting the admission requirements, do not choose to pursue a technical education or studies in science. When such talent decides not to engage in studies in science/technology, they are allocated to the so-called sci/tech reserves. In this article, sci/tech studies are understood to refer to courses in the nature and technology sectors, and laboratory courses at universities of professional education. According to this definition, courses in the agriculture and health sectors are not counted among the sci/tech studies.

Are there actually reserves of sci/tech talent?

In the second half of the 1990s, it was shown in various ways that there are large reserves of sci/tech talent in the Netherlands ([1]). The actual volume depends on the definition used for sci/tech talent, for which a distinction can be made between pupils and students.

Pupils in secondary education

In their third year, pupils in the Netherlands must choose one of four subject clusters ([2]):

- nature and technology (N&T)
- nature and health (N&H)
- economics and society (E&M)
- culture and society (C&M)

The central idea behind this classification is to make pupils reflect at a rather young age on the direction in which they want to be further educated. To generate sufficient influx into technical studies, a requisite number of pupils will have to opt for the preparatory nature and technology subject cluster.

In the Netherlands, sci/tech talent is certainly adequately available, but in many cases the choice of a non-technical education is made on economically rational grounds. The influx into the nature and technology subject cluster steadily declined during the 1990s, but has stabilised in recent years (Figure 1). At the same time, the nature and health subject cluster clearly gained in popularity. So, we observe a shift towards 'more-human-oriented' technology. An experiment called 'Human Technology' successfully conducted at the Hanze PHE Institute demonstrates that students transferring from the non-nature and technology subject clusters can successfully complete studies in technology in PHE.

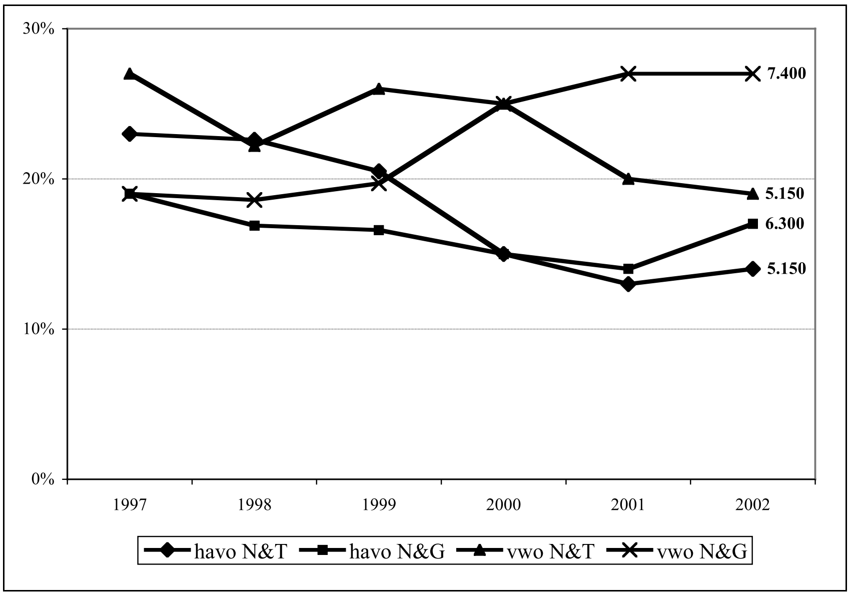
When looking at secondary-school pupil decision-making on the subject cluster to be taken, it turns out that the choice is partic-

the effect of these measures seems to be substantial, they leave much to be desired in terms of cost-effectiveness. Moreover, they are still simulations, and the measures have not (yet) been tested in practice. Therefore, additional (experimental) research on such policy measures continues to be desirable.

([1]) Hop et al., (1999); Roeleveld (1999); Bloemen and Dellaert (2000); De Jong et al. (2001).

([2]) The main inflow in higher education in the Netherlands runs through 5-year general secondary education (HAVO) and 6-year pre-university education (VWO).

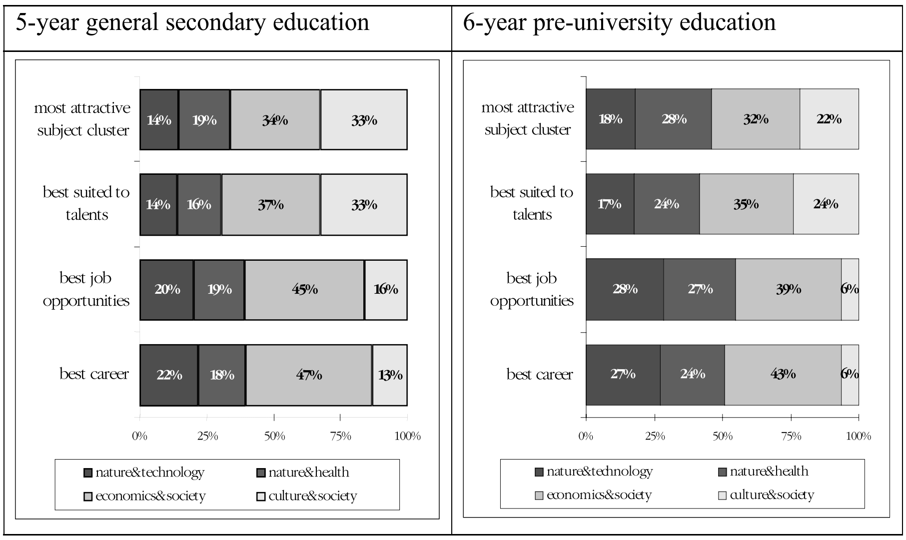
Opting for nature subject clusters* **Figure 1**



* additionally shown are the number of students in the final exam class of 2002, per level and profile (total number of final exam students in 2002: HAVO 37 thousands and VWO 27 thousand).

Source: SEO / Aromedia (SCM, 1997-2002)

Relative weight of specific considerations in choosing a subject cluster/subject package in 2001 **Figure 2**



Source: SEO/Aromedia (2002)

ularly influenced by interest, the possibility for self-fulfilment and the prospect of a paid job. In addition, aspects such as background characteristics of the pupils, level of education of their parents, and performance at school also play a part.

Why pupils opt for the nature and technology subject cluster, is the proverbial sixty-four thousand dollar question. Using a comparison between pupils who have chosen this subject cluster and the other pupils, it is possible to give an initial outline.

While several factors influence the choice of a specific subject cluster, it is interesting that the relative weight of these factors hardly differs when comparing the different subject clusters (Figure 2). Among pupils in five-year general secondary education who had chosen the nature and technology or nature and health subject cluster, one consideration, often mentioned for making such choice, was that it would benefit their careers. At the six-year pre-university education level, a similar relationship can be observed while it is to be noted that the emphasis is on the quality of job opportunities.

Students

The extent of hidden science and technology talent among first-year students in 1995 and 1997 has been calculated on the basis of data from the DHO research project (See Annex 1). The fact that the aptitude of students and pupils for science/technology does not change from one year to the next gives this analysis the proper relevance. The results are shown in Table 1. This relates to the national totals in non-sci/tech studies with at least mathematics and physics in their subject packages and an average final examination mark for science subjects of seven or higher. Based on the processed sampling data from the 1995 cohort and the 1997 cohort it can be concluded that there is a large amount of hidden sci/tech talent available in higher education. To simplify somewhat the interpretation of this data, it is worthwhile to know that in 1997 there were 12 900 sci/tech students at the level of PHE and 7 000 at the level of AHE.

The above figures show that the number of women that may be characterised as hidden sci/tech talent is not particularly large compared with men. Although the proportion of hidden talent for women is indeed larger, the group that may be included in sci/tech talent, based on the choice of mathematics and physics and the relative marks obtained, is much smaller than for men.

Figure 3 shows the sectors where a substantial portion of science and technology talent (having mathematics and physics in their subject packages with at least a seven for science subjects) was to be found

among first-year students of the 1997/98 cohort.

In PHE, these students are found mostly in the economics sector and, to a lesser extent, in education and agriculture. In AHE, the portion of sci/tech talent is highest in health and economics and, to a lesser extent, in the social sector. In the other sectors of both PHE and AHE the portion of sci/tech talent is less than 10 %.

Following the introduction of the renewed second phase in secondary education and the requirement to choose one of the compulsory subject clusters, the situation has changed extensively. For this reason we are using data from the sci/tech reserves in AHE for the academic year 2002-03 provided by the Office of Institutional Research of the University of Amsterdam (UvA). The extent of the reserves of sci/tech talent has been calculated - based on the 2002 December 1 counts - for the total of AHE and for most universities individually (see Table 2).

Judging by the more than 8 000 students with a nature and technology or nature and health subject cluster in pre-university education, there are reserves of 23 %, approximately 1 800. They are largest at Erasmus, UvA and Maastricht and smallest at the VU.

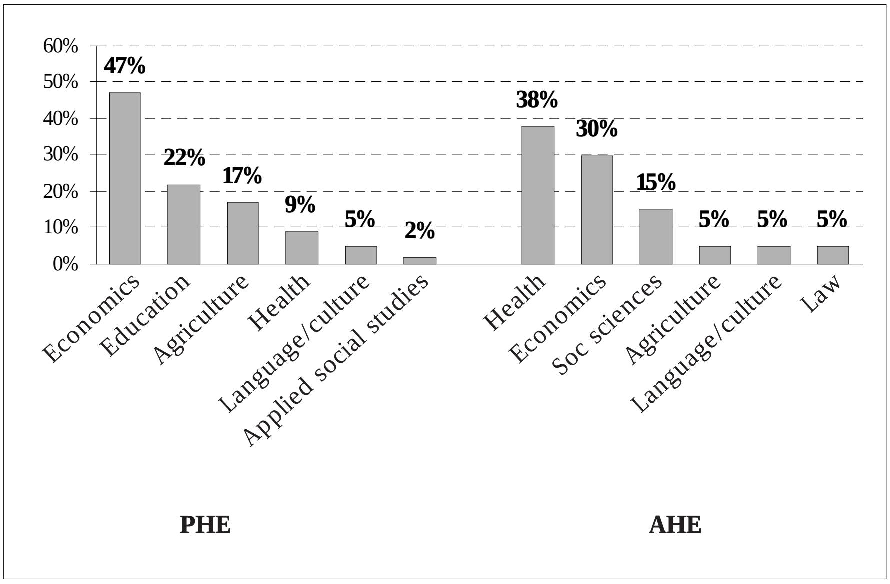
It is not possible to make an accurate comparison with the former situation because the nature and health subject cluster is intended for both science and technology courses and courses in the health and agriculture sectors. In the former situation, a large portion of the reserves of approximately 3 450 students in higher education opted for one of these two sectors. So, it seems the reserves have not diminished after the introduction of the subject clusters.

Hidden sci/tech talent quantified **Table 1**

	1995 cohort			1997 cohort		
	man	woman	total	man	woman	total
AHE students	1 150	1 050	2 200	1 900	1 550	3 450
PHE students	3 000	450	3 450	3 800	700	4 500

Source: de Jong, et al. (2001), p. 66

Percentage of sci/tech talent in sectors of PHE and AHE **Figure 3**



Source: de Jong, et al. (2001)

Overview of science and technology reserves in the total of AHE (by institution) **Table 2**

Pre-university education nature/health/technology subject cluster	Science/technology reserves
Erasmus University (Erasmus)	58 %
State University at Groningen (RUG)	38 %
Maastricht University (U Maastricht)	35 %
University of Amsterdam (UvA)	35 %
Catholic University Nijmegen (KUN)	31 %
Leiden University (U Leiden)	31 %
Utrecht University (U Utrecht)	27 %
Free University (VU)	21 %
Total Netherlands Academic Higher Education	23 %

Source: CBS, 2002 Dec. 1 count; Office of Institutional Research, University of Amsterdam

Inducements for studies in science and technology

If the minister wants to take real action on the objectives as formulated in Brussels, the sci/tech reserves of the Netherlands will have to be addressed. How can the decision-making process of a group of students - potentially successful in science or technology but opting for other studies - be influenced? Are there any conceivable measures that can ‘tempt’ this group into choosing a technical or scientific education? Such ‘steering’ of the choice of study can, in principle, be achieved through various direct and indirect stimuli.

Indirect methods relate to the perception students have about the course of their studies and what will be the added value of such studies. In this context one could think, for instance, of how students estimate their chances of obtaining a diploma and what

Expectations from their own studies as compared with studies in sci/tech of students in AHE with a nature and technology subject cluster **Table 3**

		income			
Education	chance of success	starting	top	job opportunity	% of total non-sci/tech
Economics	+	+	+	+	23
Health	+	+	+	+	40
Law	+	-	+	+	7
Social	+	-	-	-	20
Language and Culture	+	-	-	-	10
(+ = own study scores higher)					
Source: de Jong et al. (2001)					

they believe will be their position in the labour market.

Students always look on their own studies as offering the best chances of obtaining the diploma. In general, the differences for science or technology range between 15 and 20 percentage points. This means that students who qualify for education in science or technology choose a subject in which they believe they stand a significantly better chance of obtaining their diplomas. Table 3 indicates, in addition to the chances of success, an overview of the other results of the analyses for first-year students in AHE with a nature and technology subject cluster. A '+' in this table indicates that their expectation is higher for their own studies than for the study in science/technology. The last column shows how this group is distributed among the various sectors.

In terms of all characteristics, an ample majority (63 %, economics and health) of the students have higher expectations from their own studies than from science/technology. It is perfectly clear why these students did not choose to study science or technology. This also applies to law students. In science/technology, they expect only a higher starting salary; in terms of the other characteristics, their own studies score higher. In contrast, students in the social and language and culture sectors have higher expectations from studying science/technology with regard to income and chances of finding a job but consider their chance of succeeding in a science or technology course to be lower. Given the outcome of the decision-making process, the lower chance of success apparently outweighs the expected benefits of science/technology.

The results in Table 3 also provide insight into the possibilities of stimulating students by financial incentives to choose a scientific education. Most students both consider the uncertainties of studying science/technology (affecting success) greater and also expect to gain more from their own studies, in income and job opportunities. In order to influence the decision-making process of these students, both these aspects must be compensated. This probably means that these students can be induced to opt for science/technology education only through strong stimuli. For students in the social and language and culture sectors, only the chance of success seems to be a barrier. This group may possibly be tempted by changes in the study programmes offered in science and technology.

To assess the effect of direct stimuli, students of the 1997 cohort of freshmen were asked whether a number of possible policy measures would have influenced their choice in favour of science or technology. We can use this data to make a cautious estimate of the additional number of students that would result from particular measures (See Felsö, Van Leeuwen and Zijl, 2000; Berkhout and Van Leeuwen, 2000). Students from non-sci/tech courses were selected for indicating that they would 'definitely' (score 10) have chosen a science or technology course if a certain measure had been introduced and the figures assessed for the number of first-year students in the non-sci/tech courses concerned. Table 4 shows the results for six specific measures.

The measures are more effective for students in PHE than for students in AHE. The measures can be roughly divided into two groups. A job guarantee has about the same effect as no tuition fees for sci/tech studies and a better tie-up between secondary education and higher education. These measures cause an increase in the number of students of some 8.5 % in PHE and 5.5 % in AHE. The other three measures are less effective and hover around 6 % (PHE) and 4 % (AHE).

In addition to the effectiveness measured in numbers of additional sci/tech students, the cost-effectiveness of some of the measures considered has been calculated. The yield (additional sci/tech students) was related to the costs involved for a particular measure ([3]). The calculations (see Table 5) are based only on the first year of study.

([3]) Introducing a job guarantee, improving the tie-up or increasing the chance of success also entails costs, but they are difficult to determine with accuracy and are borne only partly (directly) by the government. For this reason, cost-effectiveness has not been calculated for these measures.

Additional students choosing a study in science/technology as a result of several concrete policy measures **Table 4**

		Additional first-year students choosing a sci/tech study following the introduction of					
		no tuition fees sci/tech study	additional grant sci/tech study of EUR 340 per month	90 % chance of success in a sci/tech study	better tie-up between secondary and higher education	job guarantee for students in sci/tech study	higher starting salary after a sci/tech study
increase in sci/tech PHE	number	5 300	3 950	4 500	6 150	7 000	4 000
	% point	7,5 %	5,7 %	6,3 %	8,6 %	9,8 %	5,7 %
increase in sci/tech AHE	number	1 600	1 150	1 200	1 400	1 750	700
	% point	5,4 %	4,0 %	4,3 %	4,7 %	6,0 %	2,2 %

Source: Felsö, Van Leeuwen and Zijl (2000)

Costs of some concrete policy measures aimed at stimulating opting for a study in science/technology **Table 5**

		Additional students choosing a study in science/technology					
		no tuition fees sci/tech study	additional grant sci/tech study of EUR 340 per month	90 % chance of success in a sci/tech study	better tie-up between secondary and higher education	job guarantee for students in sci/tech study	higher starting salary after a sci/tech study
PHE							
increase in sci/tech	number	5 300	3 950	4 500	6 150	7 000	4 000
	% point	7,5 %	5,7 %	6,3 %	8,6 %	9,8 %	5,7 %
Cost of measure	EUR million	23	68	-	-	-	23
- already opted for sci/tech	EUR million	11	53	-	-	-	18
- additional sci/tech	EUR million	7	15	-	-	-	6
Cost per student (1).	EUR	4 400	17 200	-	-	-	5 700(2).
AHE							
increase in sci/tech	number	1 600	1 150	1 200	1 400	1 750	700
	% point	5,4 %	4,0 %	4,3 %	4,7 %	6,0 %	2,2 %
Cost of measure	EUR million	11	33	-	-	-	10
- already opted for sci/tech	EUR million	9	28	-	-	-	10
- additional sci/tech	EUR million	2	4	-	-	-	1
Cost per student (1).	EUR	7 000	29 000	-	-	-	16 200(2).

(1) The total cost of the particular measure in the first year per additional science student. Example of calculation: for students in PHE, the abolition of tuition fees for sci/tech studies costs EUR 23 million [= (12 900+5 300) * EUR 1 278] and results in 5 350 additional students; cost per student [4 400 = 23 000 000/5 300].
(2) First year EUR 454 additional salary per month, the government contributing 50 % and it being assumed that 50 % of the students will later actually qualify for the bonus.

Source: Felsö, Van Leeuwen and Zijl (2000)

Looking at the three measures for which cost-effectiveness has been calculated, we may conclude that abolishing tuition fees not only leads to the highest number of additional students, but is also the most cost-effective. In the first year of study, the costs of this measure roughly amount to EUR 4 400 (PHE) and EUR 7 000 (AHE) for each additional student in a science/technology course.

Conclusions

In this article, we have shown that the Netherlands has ample sci/tech reserves. Under present conditions, most of them are choosing a non-technical study on rational grounds. Specific measures could potentially lead to a substantial increase in the influx into science and technology. The costs involved, however, are considerable, and cost-effec-

tiveness is usually low. Also, the measures studied have not been tested in practice and the margin of uncertainty is wide. Both the government and industry have called for a Delta Plan to be drawn up for science/technology. In this respect, it is important to reflect on a stimulating policy focused on educational institutions (adoption of best practices), pupils (inducing them to choose technology) and enterprises (offering entrants experience-gaining opportunities and career prospects). Since we still do not know enough about the degree to which study options can be influenced, several studies notwithstanding, the effects of any adaptation of the student grant system are uncertain. Policy changes and investments in education should, therefore, be coupled with scientifically controlled experiments, the effects of which are evaluated. We shall then know in a few years how all this works out and which measures may be expected to have an effect.

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Annex I

The annual Student monitor (de Boom et al., 2003) publishes data on students based on a representative sampling from the entire Dutch student population in higher education. This sampling is used to outline a reliable, year-on-year picture of students in Dutch higher education. This is done on the basis of a sampling that is stratified by type of higher education (PHE/AHE), academic years and sectors.

The Study choice monitor (SCM) is the product of cooperation between Aromedia and SEO Amsterdam Economics. In the SCM, pupils' behaviour in choosing their studies is charted from a questionnaire to be completed by the pupils by computer. They are assisted in this by the careers master. The population investigated comprises the pupils of the final two school years in five-year general secondary education and six-year pre-university education. The SCM started in 1996 with a total response from over 5 000 pupils. Today, more than 6 000 pupils complete the questionnaire each year (more than 11 % of the total population).

In the research project Participation in higher education (DHO), SEO Amsterdam Economics and SCO-Kohnstamm Institute, both of the University of Amsterdam, gathered data on students in higher education who had enrolled for the first time at an AHE or a PHE institute in the academic years 1995/96 and 1997/98. Both samplings are stratified by type of education (PHE/AHE) and sectors (eight PHE and eight AHE). The respondents were approached in their first and second years of study.

Key words

Educational policy,
labour demand,
science policy,
motivation,
choice of studies,
higher education.

Annex II

The Dutch education system

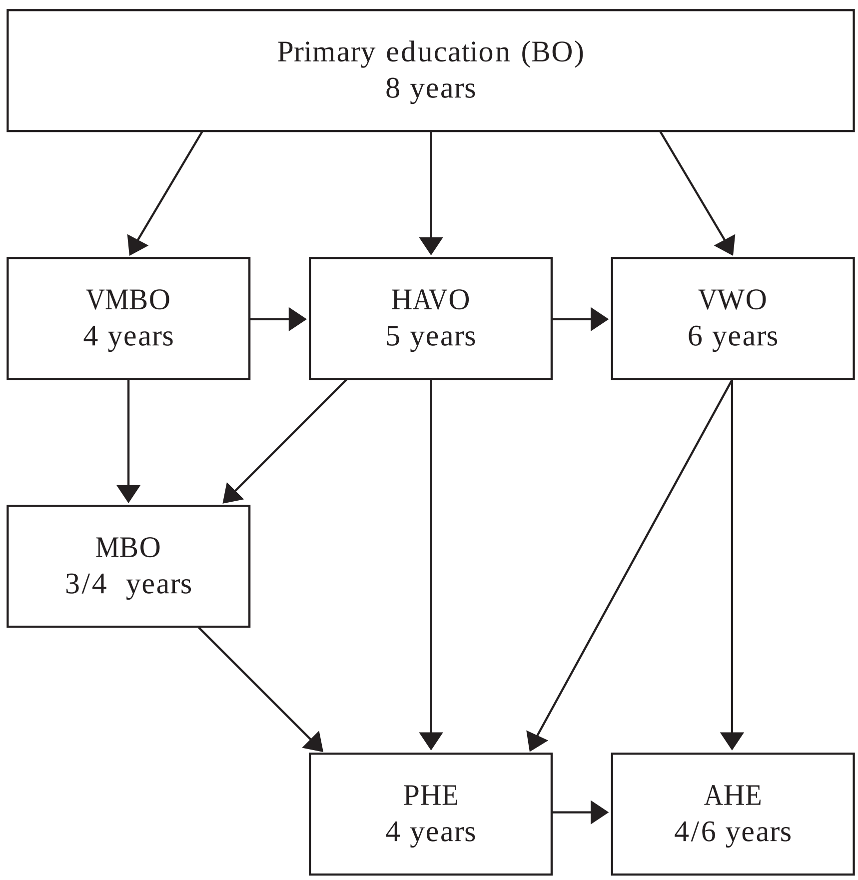
Full-time education is compulsory in the Netherlands for all children aged 5 to 15. For 16 and 17 year olds, partial education is compulsory.

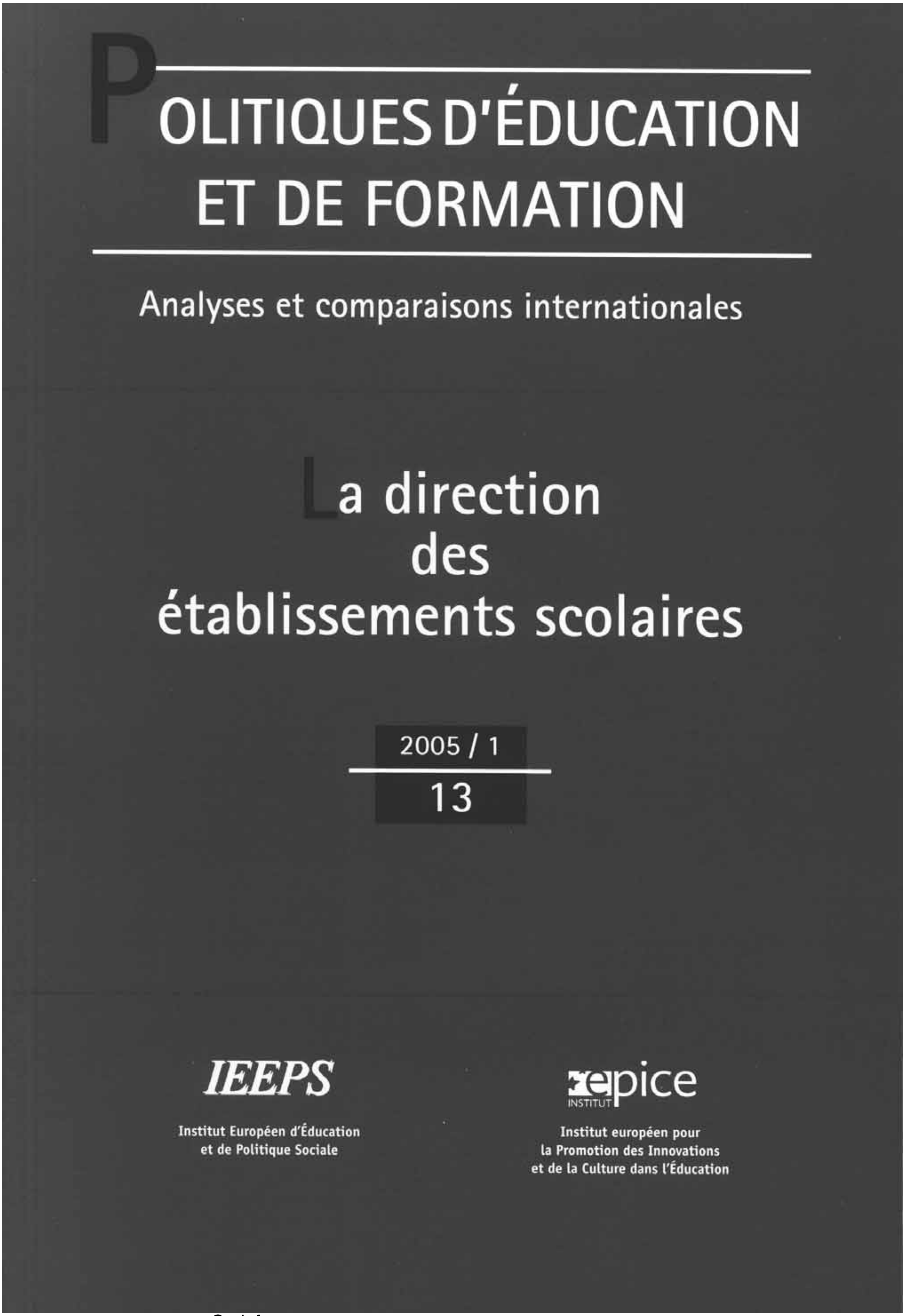
Children begin their school careers at the age of four in primary education (BO). Later, most of them move on to secondary education (VO), which branches into:

- ❑ pre-vocational secondary education (VMBO);
- ❑ senior general secondary education (HAVO);
- ❑ pre-university education (VWO).

After secondary education, pupils move on to senior secondary (or intermediate) vocational education (MBO) or higher education. MBO is divided into a vocational training programme (bol) and a block/day release programme (bbl). This type of secondary education has two functions: qualifying for the labour market and for professional higher education. Dutch higher education has two levels: professional higher education (PHE) and academic higher education (AHE). Traditionally, AHE is considered to be the highest level of education. Graduation from HAVO gives direct access to PHE. Another route to PHE is through MBO. The most common way to university is six years of VWO. Another way of enrolling in university is graduation in the first year of a related type of PHE; also, graduation from PHE gives access to AHE. The figure below shows the structure of the Dutch education system.

The Dutch education system

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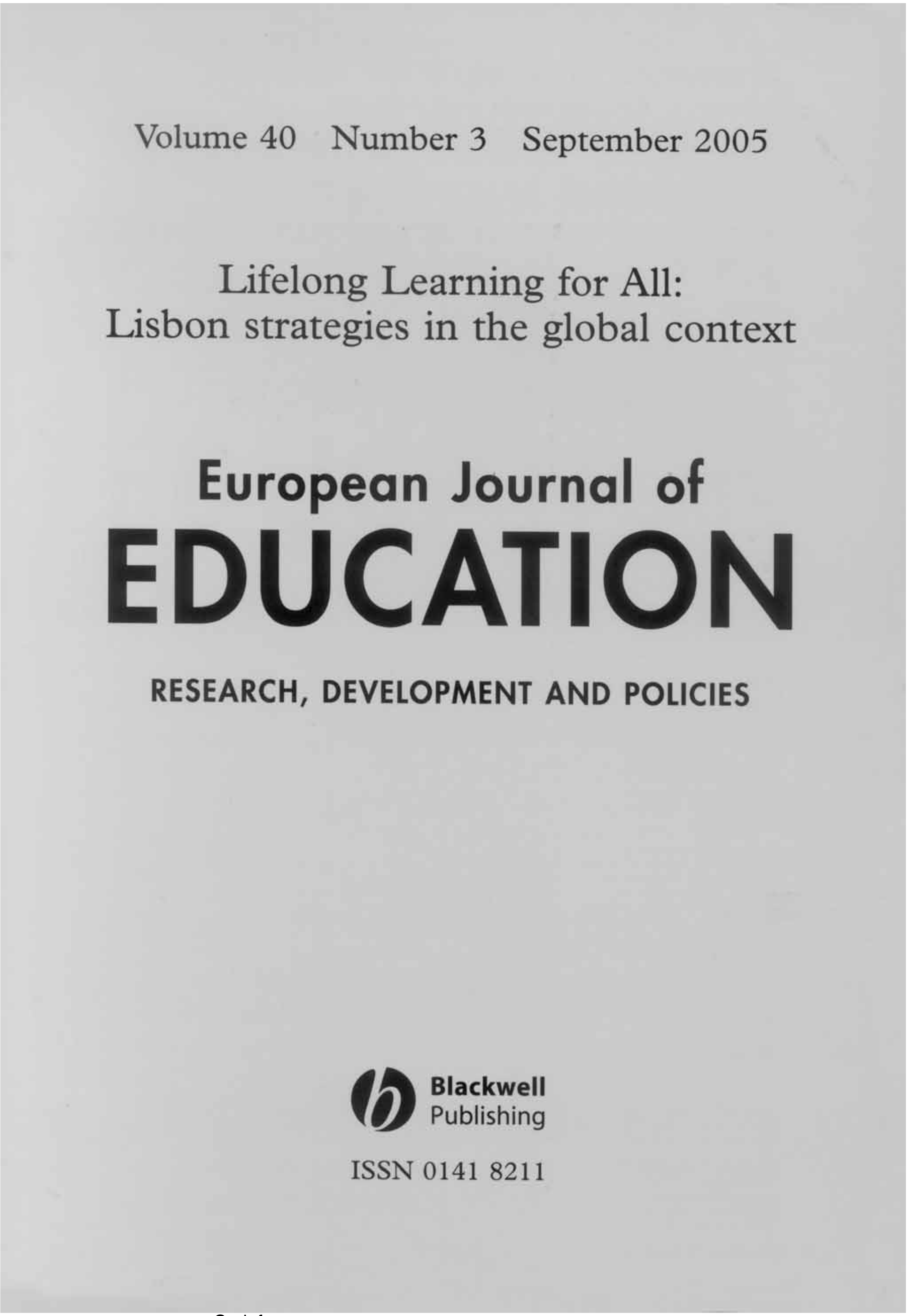
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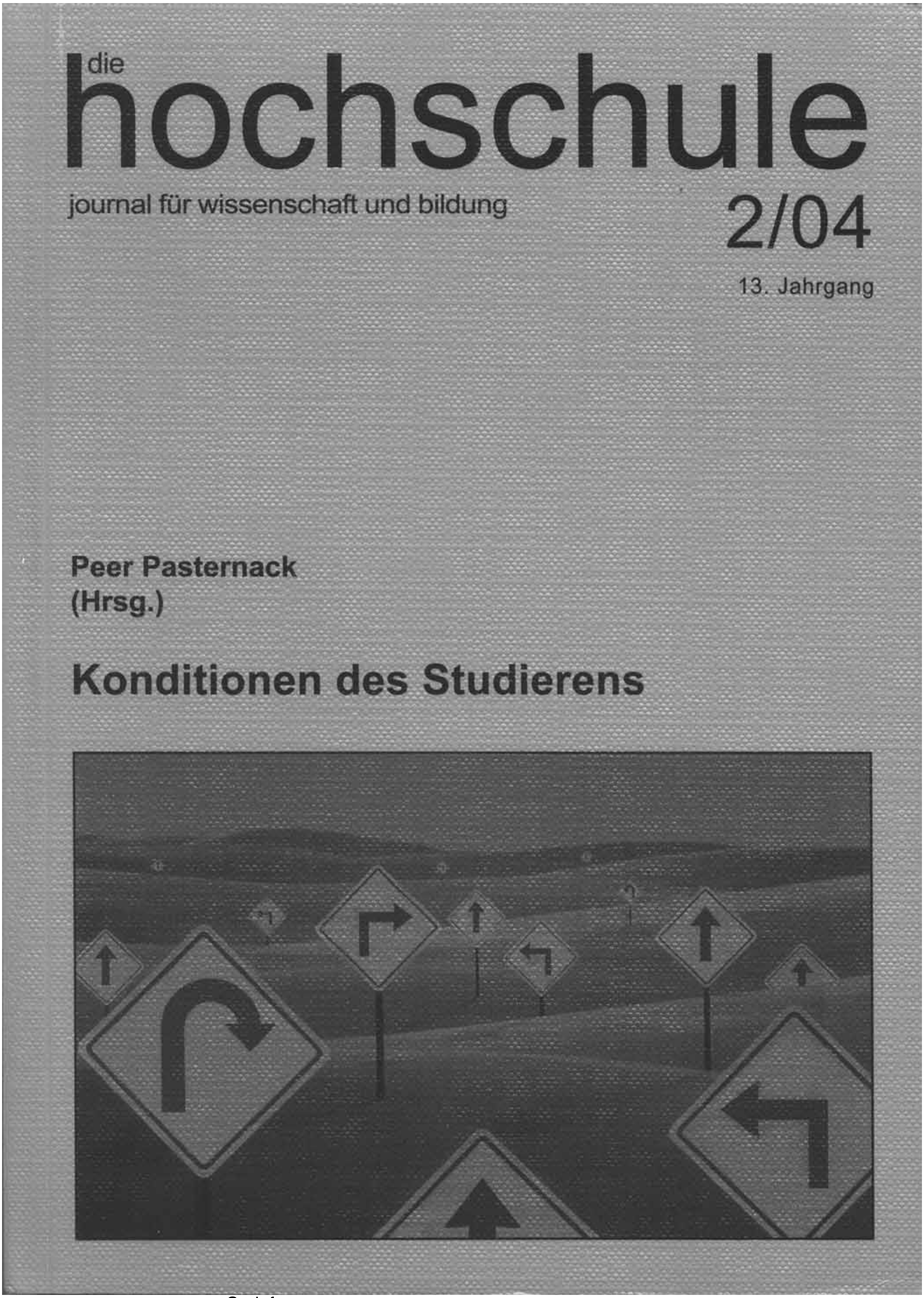

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13. Jahrgang

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